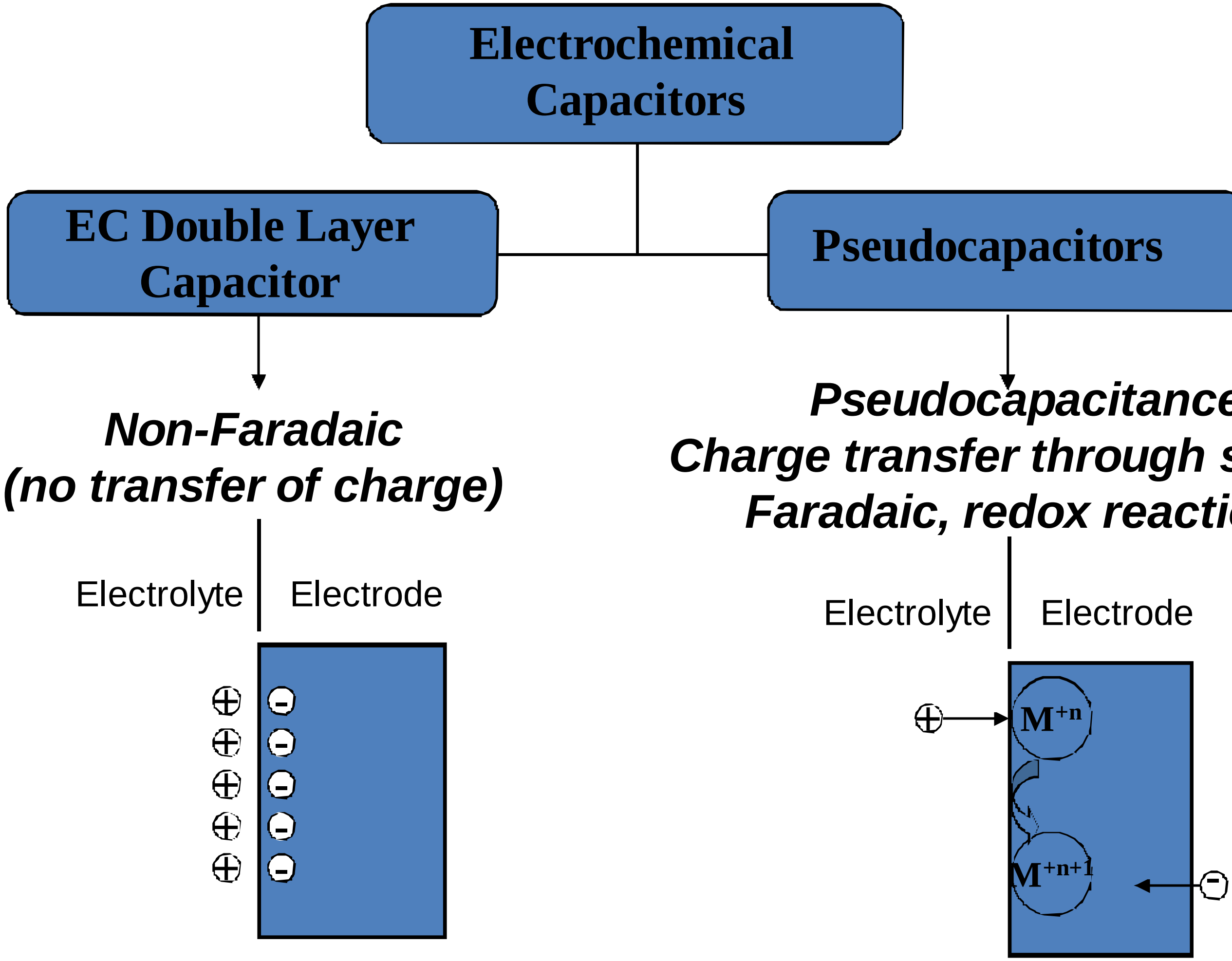
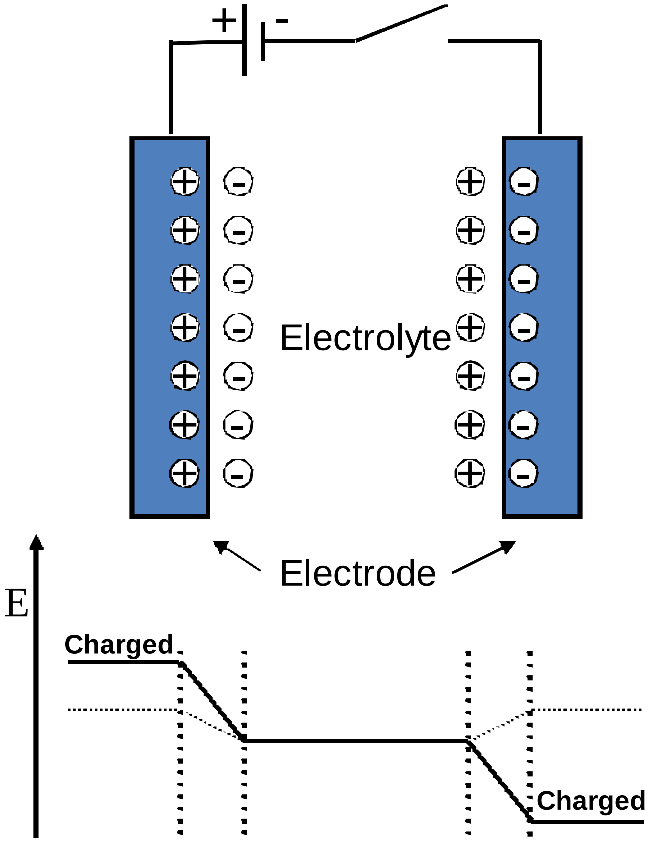
Supercapacitors

Capacitive Storage Systems



Electrochemical Double Layer Capacitors (EDLC)



EDLCs store charge electrostatically at electrode/electrolyte interface as charge separation.

C_{dl}: 10-50 $\mu F/cm^2$*

There is no charge transfer between electrode and electrolyte.

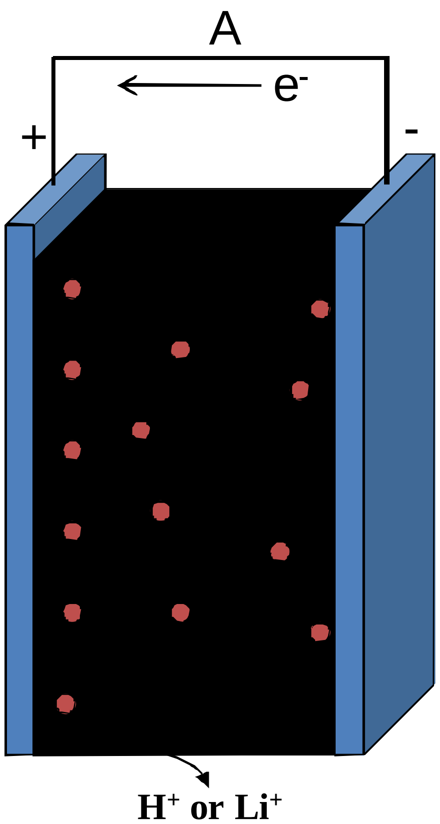
Intrinsically high power devices (short response time), limited energy storage, very high cycling stability (~10^6).

Different forms of high surface area carbon are used as an electrode material:

- activated carbon
- carbon aerogels
- carbon nanotubes

***Conway, B. E., Birss, V. & Wojtowicz, J.**
Journal of Power Sources **66, 1-14 (1997)**

Pseudocapacitors



Pseudocapacitors store by charge transfer between electrode and electrolyte.

The charge is transferred at the surface or in the bulk near the surface through adsorption, redox reaction and intercalation of ions.

Pseudocapacitors can achieve higher specific capacitance and energy density than EDLCs.

ex. Hydrous RuO_2 (700+ F/g)*

Electrode materials:

Metal oxides
Conducting polymers

***Zheng, J.P., Jow, T.R., *J. Power Sources* 62 (1996) 155**

Capacitors

• Capacitors store energy in its electric field.

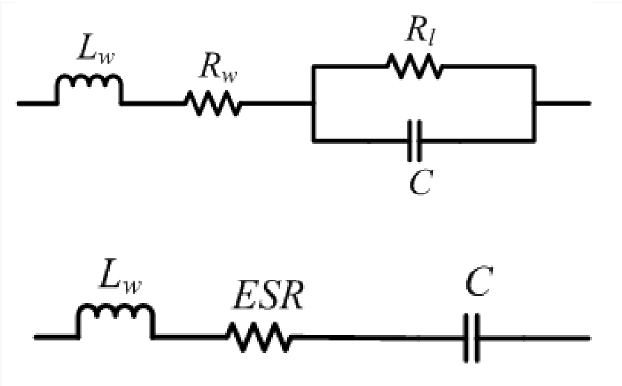
• In ideal capacitors, the magnitude that relates the charge generating the electric field and the voltage difference between two opposing metallic plates with an area A and at a distance d, is the capacitance:

$$C = \frac{Q}{V}$$

• In ideal capacitors:

$$C = \varepsilon \frac{A}{d}$$

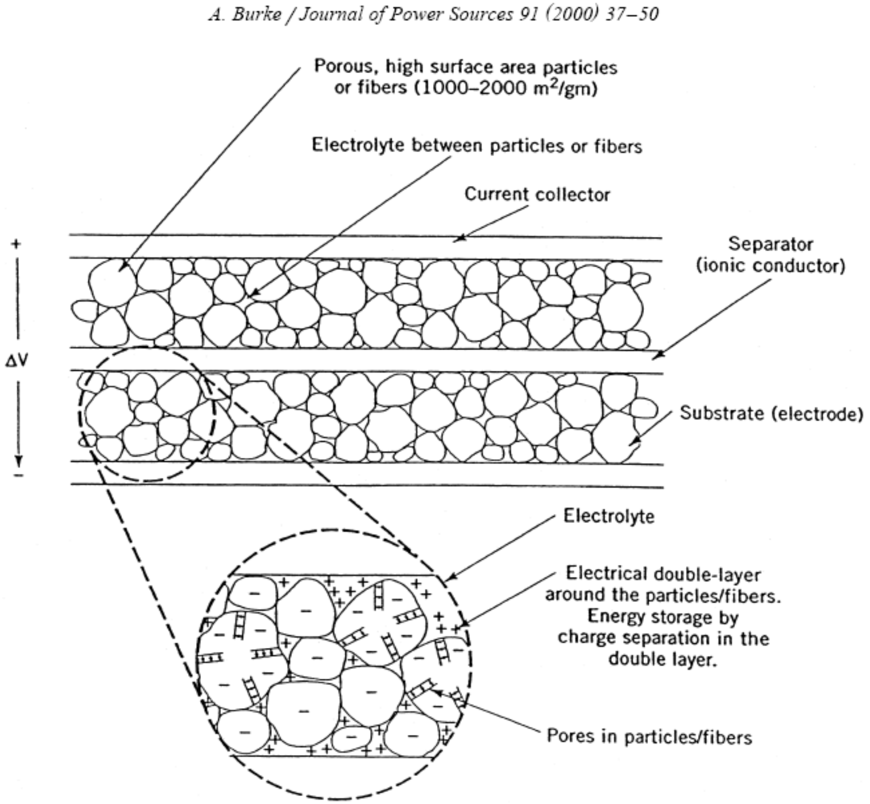
• Equivalent model of real standard capacitors:

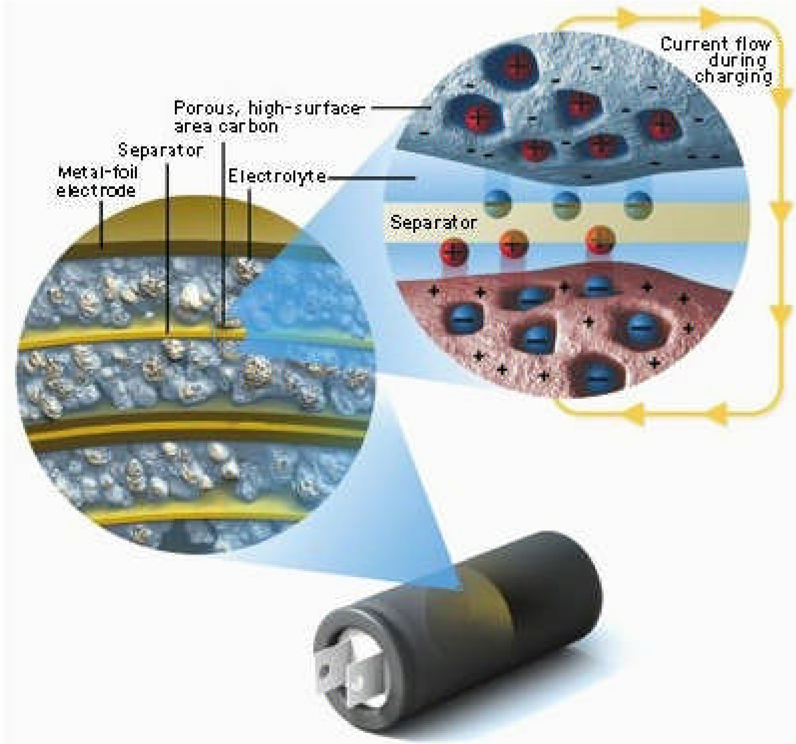


$$ESR = R_w + \frac{1}{\omega^2 R_l C^2}$$

Supercapacitors

- Double-layer technology





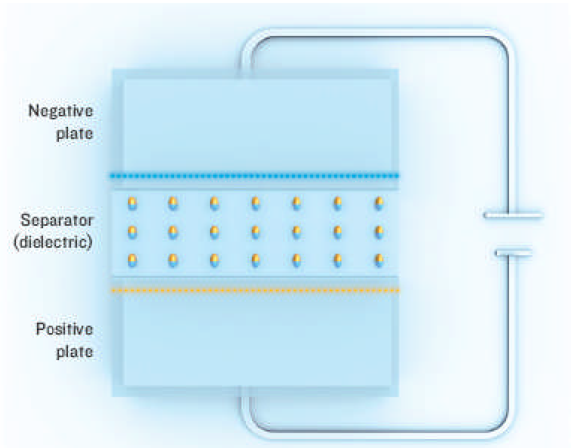
http://www.ultracapacitors.org/img2/ultracapacitor-image.jpg

- Electrodes: Activated carbon (carbon cloth, carbon black, aerogel carbon, particulate from SiC, particulate from TiC)
- Electrolyte: KOH, organic solutions, sulfuric acid.

Supercapacitors

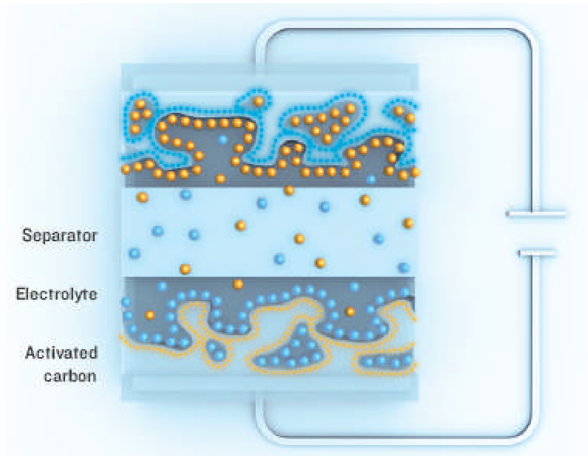
- Construction

Traditional standard capacitor



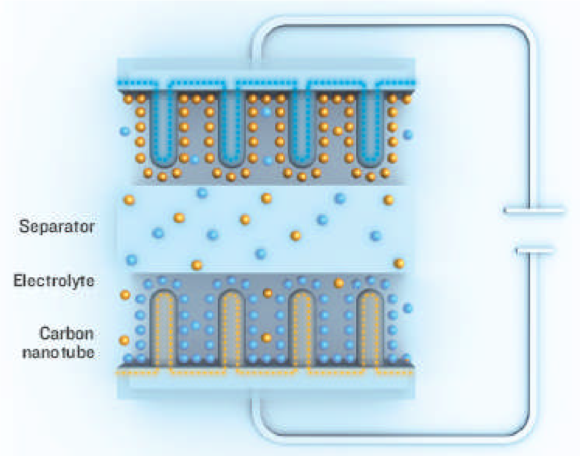
The charge of ultracapacitors, IEEE Spectrum Nov. 2007

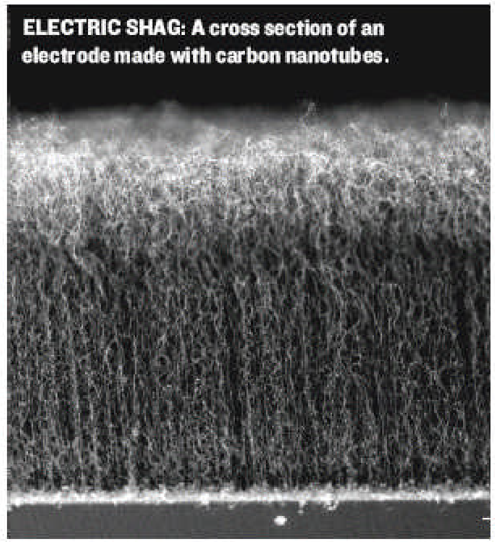
Double layer capacitor (ultracapacitor)



$$C = \varepsilon \frac{A}{d}$$

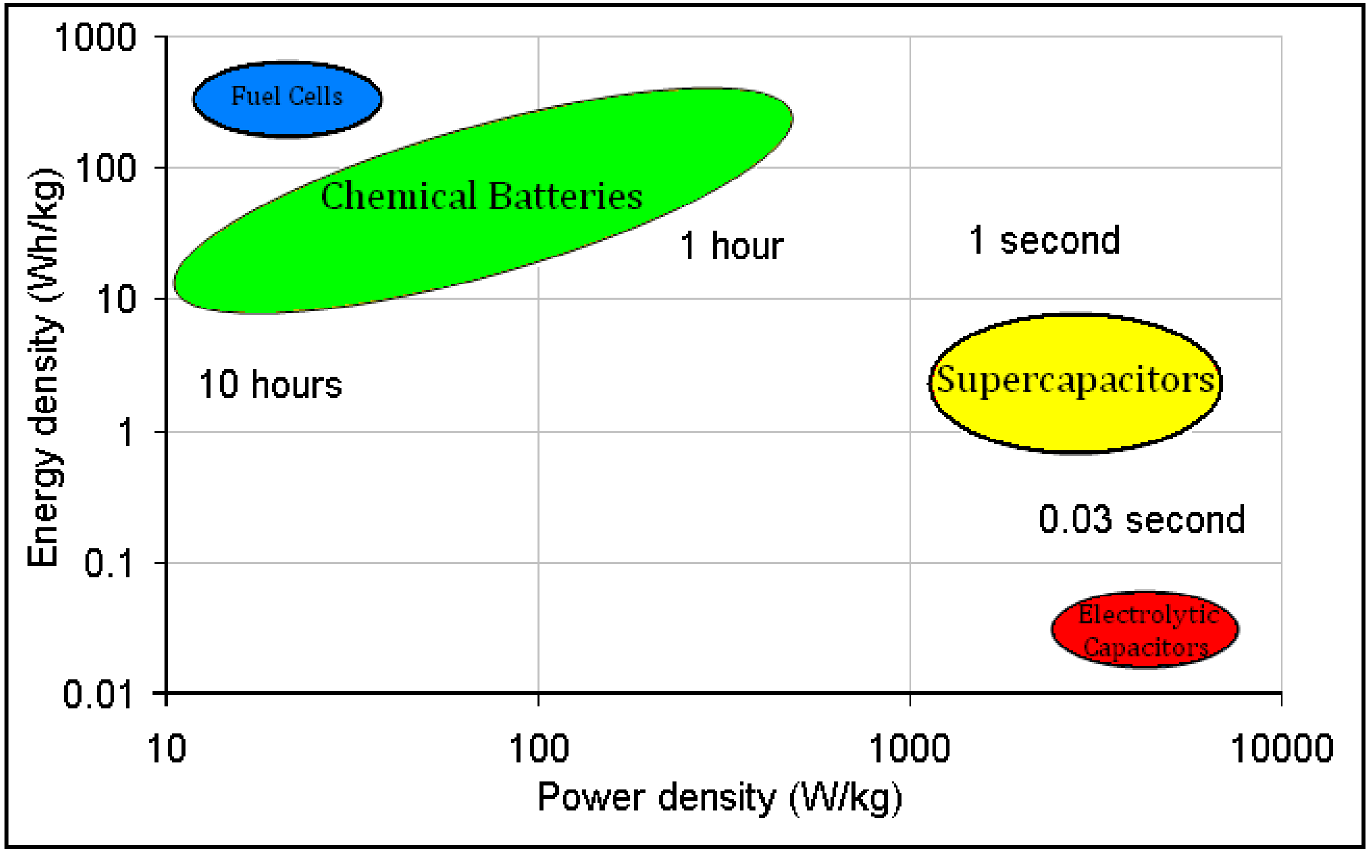
Ultracapacitor with carbon nano-tubes electrodes





- Key principle: area is increased and distance is decreased
- There are some similarities with batteries but there are no reactions here.

Comparing Batteries & Supercapacitors



- Energy density is the amount of energy stored per unit volume or mass.
- Power density combines energy density with the speed that energy can be drawn out of a device.

Rechargeable Batteries Vs. Supercapacitors

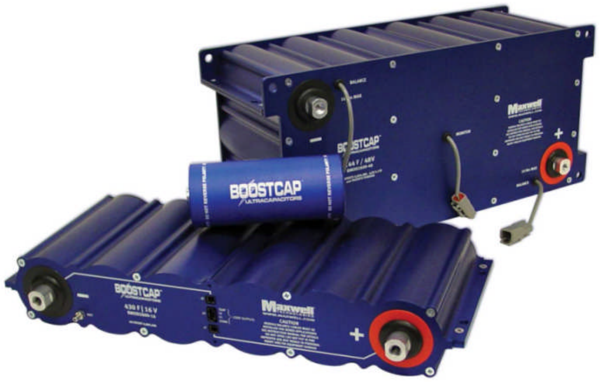
Supercapacitors:

- Higher power density
- Much faster charge and discharge rate
- Environmentally friendly
- Extremely low internal resistance or ESR
- High efficiency (97-98%)
- Over a million charge-discharge cycles

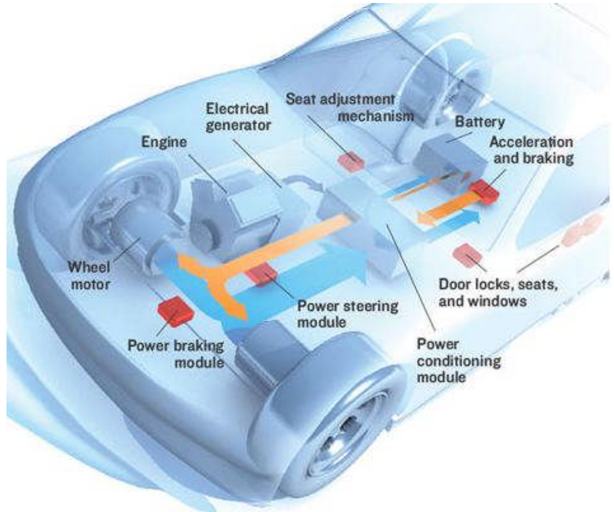
Batteries:

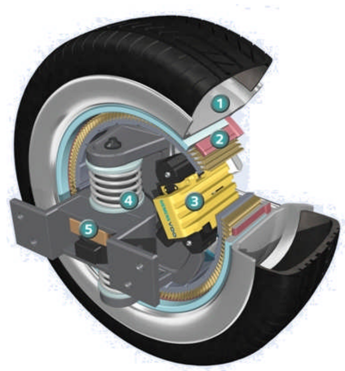
- Have higher energy density
- Typically 200–1000 charge-discharge cycles
- Contain highly reactive and hazardous chemicals
- Negatively effected by low temperatures

Applications for Supercapacitors



- Back up for uninterruptable power supplies (UPS)
- Light weight power supplies for small aircraft
- Provide short duration power for various vehicle systems such as breaking or steering
- Used to absorb power during short periods of generation such as Regenerative Braking
- Extend range and battery life in Hybrid Electric Vehicles (HEV)





Hybrid Electric Vehicles

- CSIRO in Australia [national science agency] has developed the UltraBattery, which combines a supercapacitor and a lead acid battery in a single unit
- 4x longer life cycle, 50% more power, 70% cheaper than batteries used in HEV’s